SHORT-TERM EFFECTS OF UNDERSTORY AND OVERSTORY MANAGEMENT ON BREEDING BIRDS IN ARKANSAS OAK–HICKORY FORESTS

PAUL G. RODEWALD,[1,2] Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701, USA
KIMBERLY G. SMITH, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701, USA

Abstract: Relatively little is known about the effects of uneven-aged forest management practices on eastern forest birds, despite the fact that such methods are now commonly practiced. In 1993–94, we studied the short-term effects of uneven-aged forest management on bird communities in oak–hickory forests of northwestern Arkansas. We estimated bird abundance in mature forests and on managed plots receiving either a heavy cutting of understory vegetation (understory treatment) or a combination of both understory cutting and selective cutting in the forest overstory (full treatment). Two nesting guilds and 7 of 14 species with adequate sample size showed significant treatment effects. Ovenbirds (*Seiurus aurocapillus*), worm-eating warblers (*Helmitheros vermivorus*), Acadian flycatchers (*Empidonax virescens*), and the understory-nesting guild were most abundant in mature forest. Indigo buntings (*Passerina cyanea*), white-breasted nuthatches (*Sitta carolinensis*), and eastern wood-pewees (*Contopus virens*) were more abundant on full treatment plots. Tufted titmice (*Baeolophus bicolor*) were most abundant on mature forest and understory treatment plots. The canopy-nesting guild was most abundant on understory and full treatment plots. Our results suggest that if removal of understory vegetation was practiced widely in the Arkansas Ozarks as part of uneven-aged management, populations of some ground- and shrub-nesting forest interior species of birds could be negatively affected, whereas a few forest canopy and edge species may respond positively. Future research on this type of uneven-aged management should examine effects of removing varying amounts of understory vegetation on both forest interior bird populations and forest regeneration.

JOURNAL OF WILDLIFE MANAGEMENT 62(4):1411–1417

Key words: Arkansas, Nearctic–Neotropical migratory birds, oak–hickory forests, Ozark Mountains, uneven-aged forest management.

Populations of several species of Nearctic–Neotropical migratory songbirds are believed to be declining (Robbins et al. 1989, Hagan and Johnston 1992, Peterjohn and Sauer 1993, Robinson 1997). One suggested cause of decline has been forest fragmentation and its associated effects on North American breeding grounds (reviewed in Askins et al. 1990). Although most research has examined forest fragmentation created by agriculture, suburban development, or both, there is also much concern over the effects of forest management on songbird populations (Finch and Stangel 1993, Martin and Finch 1995).

The effects of even-aged forest management (e.g., clearcutting) on eastern forest birds are relatively well studied (Conner and Adkisson 1975, Webb et al. 1977, Conner et al. 1979, Strelke and Dickson 1980, Yahner 1987, Thompson et al. 1992, Rudnicky and Hunter 1993), but little information exists on other practices. Even-aged forest management creates stands dominated by trees of 1 age class. Uneven-aged management creates stands of 3 or more tree age classes by cutting individual trees (single-tree selection) or groups of trees (group-selection cutting) from a stand, which allows for smaller volume harvests at shorter time intervals (Smith 1986).

Although several studies have examined effects of uneven-aged methods on western forest birds (Franzreb and Ohmart 1978, Szaro and Balda 1979, Mannan and Meslow 1984, Medin 1985, Morrison 1992), eastern forests have received relatively little attention (Webb et al. 1977, Chadwick et al. 1986, Annand and Thompson 1997). Because eastern forests differ greatly from western forests in both habitats and bird communities, research conducted in the West may be unsuitable for guiding forest management policy in the East. Our study is also important because effects of the specific uneven-aged practices on birds are unstudied.

[1] Present address: School of Forest Resources, 302 Forest Resources Lab, The Pennsylvania State University, University Park, PA 16802, USA.
[2] E-mail: pgr2@psu.edu

Before new forest management practices become widely used, managers need to know the effects these practices will have on bird populations so they can make more informed land-use decisions.

In response to public opposition to even-aged forest management practices, especially clearcutting, uneven-aged practices have recently become much more common in the Ozark-St. Francis National Forest. An implicit assumption of these practices seems to be that forest birds will be less affected by uneven-aged management than by clearcutting, because fewer trees are removed from stands and large abrupt edges are not created. However, few data exist to support this assumption.

In this study, we examined the short-term effects of uneven-aged forest management on bird communities in a heavily forested region of the Ozark-St. Francis National Forest, Arkansas. Two stages of the management practice were studied. The first involved an extensive cutting of understory vegetation (understory treatment) to lower competition and promote regeneration of desirable tree species (primarily oaks [*Quercus* spp.]). Overstory treatment followed understory treatment and included a thinning of overstory trees and 1 group-selection cut. Abundances of bird species and nesting guilds were compared among understory treatment, combined understory and overstory treatment (full treatment), and mature forest plots.

STUDY AREA

The study area was located in the eastern part of the Ozark-St. Francis National Forest in northern Pope and southern Newton counties, Arkansas. Forests in this area are entirely oak–hickory with very little pine (*Pinus* spp.); elevations ranged from 400 to 620 m. Common tree species in the study area included white oak (*Quercus alba*), northern red oak (*Q. rubra*), black oak (*Q. velutina*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), black gum (*Nyssa sylvatica*), mockernut hickory (*Carya tomentosa*), black hickory (*C. texana*), black cherry (*Prunus serotina*), and flowering dogwood (*Cornus florida*).

METHODS

Forest Treatments

Treatments were completed in summer and early fall in both 1992 and 1993, after bird surveys were conducted. Managed plots (4.5 ha each) received either an understory treatment or both an understory and overstory treatment (full treatment). In spring 1993, we surveyed 16 mature forest (control plots) and 8 understory treatment plots. In late summer 1993, the 8 understory treatment plots received an overstory treatment (i.e., full treatment), while 8 additional forest plots received an understory treatment. As a result, we surveyed 8 full treatment, 8 understory treatment, and 16 mature forest plots in spring 1994. Equal numbers of mature forest and managed plots were located on north- or east-facing and south- or west-facing aspects.

During understory treatment, all understory trees of unmerchantable species taller than breast height (1.4 m) and <14 cm diameter at breast height (dbh) were cut and left in place. The most commonly cut species were flowering dogwood and black gum. Well-formed saplings of oak, hickory, ash (*Fraxinus* spp.), black cherry, and black walnut (*Juglans nigra*) (i.e., desirable species) were not cut. Because unmerchantable species typically accounted for a high proportion of understory trees prior to treatment, understory tree density was usually very low after treatment, creating an open, park-like understory.

Forest overstories of 8 understory treatment plots were thinned in summer 1993 to a basal area of 15 m^2/ha (4 plots) and 19 m^2/ha (4 plots). Merchantable trees were harvested, unmerchantable and poorly formed desirable tree species >14 cm dbh were cut and left in place, and no snags were cut. In addition, a group-selection cut was completed in a randomly selected location within the plot. Diameters of group-selection openings ranged from 32.4 to 49.2 m ($\bar{x}$ = 40.5 m).

Point counts in mature forest were located in mature, secondary oak–hickory forest at least 100 m from the edges of managed plots. These areas were selected based on visual similarity to precut conditions of managed plots. We believe differences were insignificant in vegetation structure and bird species composition between mature forests and managed plots prior to treatment.

Vegetation Plots

We established 4 circular vegetation analysis plots at each point count, using slightly modified methods of James and Shugart (1970). Vegetation plots were completed at 16 mature forest, 8 understory, and 8 full treatment point counts. One vegetation plot was located at the center of each point count, and 3 were located 35 m from the center in directions of 120, 240, and 360°, so that the 4 plots were within each 50-m-radius point count.

We measured 17 habitat characteristics. Within a 5-m radius of the vegetation plot center, shrubs (measured 10 cm aboveground) and saplings (measured 1.4 m aboveground) >0.5 m in height were classified as "stems" and recorded by species in size classes 0–2.5 cm and 2.5–8.0 cm. Percentages of ground cover <0.5 m in height were estimated within this 5-m circle as either grass, shrub, forb, fern, downed log, or leaf litter. Four measurements of canopy cover were taken with a spherical densiometer, and average canopy height was visually estimated. Within an 11.3-m radius, we recorded trees by species in dbh classes of 8–23, 23–38, and >38 cm. Vegetation density profiles were recorded at 5 random locations along each of 2 transects running north–south and east–west through the plot center. At each location, points where live vegetation and dead vegetation contacted a randomly placed, vertical 2-m pole were recorded between 0–1 m (low live hits, low dead hits) and 1–2 m (high live hits, high dead hits).

Bird Surveys

We used 50-m-radius point count methodology to record all birds seen or heard for 10 min (Hutto et al. 1986). A single point count was located at the center of each managed plot and in mature forest adjacent to managed plots. No point counts were located within group-selection cuts. We conducted 5 bird surveys at each point count in 1993, and 4 were conducted in 1994. Surveys were conducted between 0600 and 1030 from 26 April to 8 June in 1993 and 1994.

Data Analysis

We used data on 17 habitat characteristics and multivariate analysis of variance (MANOVA) to test for an overall difference in habitat structure among treatments. Step-wise discriminant analysis (SAS Institute 1989) was used to determine which habitat characteristics were most significant in discriminating among treatments. We used Duncan's multiple range test to examine pairwise differences among treatments for each habitat variable selected in the discriminant analysis. Some habitat variables were log or square-root transformed to improve normality (Sokal and Rohlf 1995).

We classified 24 bird species into 3 mutually exclusive nesting guilds: understory nesters (i.e., forest ground and shrub nesters), cavity nesters, and canopy nesters (i.e., subcanopy and canopy nesters; Table 1). Nonbreeding migrants and species recorded <10 times during the study were not included in guilds. A brood parasite, the brown-headed cowbird (*Molothrus ater*), and an edge habitat species, the indigo bunting, were not included in any guild. Nesting guilds were used instead of foraging guilds because we expected forest management practices would more directly affect nesting habitat.

We calculated a single mean abundance value for each species and nesting guild from the 4–5 surveys completed at each point count location (Table 1). We used the Kruskal-Wallis test (chi-square approximation; SAS Institute 1989) to test for year and treatment effects because data could not be transformed to a normal distribution. Nesting guild and species abundance data from mature forest controls showing no year effect (α = 0.05) were pooled separately by year for analyses; species and guilds that showed a year effect were analyzed separately by year. We used guilds and individual species exhibiting significant overall treatment effects (α = 0.05) in separate pairwise tests examining abundance among the 3 treatments. We analyzed abundance data for the 14 most common bird species recorded on surveys.

RESULTS

Habitat Analysis

The 3 treatments differed in vegetation structure ($F_{34,26}$ = 13.7, P < 0.001; Table 2). Numbers of 2.5–8.0 cm dbh stems ($F_{2,29}$ = 34.4, P < 0.001) contributed the most to discrimination among treatments, followed by percent shrub coverage ($F_{2,28}$ = 23.4, P < 0.001), and then numbers of trees 8–23 cm dbh ($F_{2,27}$ = 7.6, P = 0.002). Mature forests were different (α = 0.05) from understory treatments in having 10.8 times more stems 2.5–8.0 cm dbh, 1.6 times more trees 8–23 cm dbh, and 3.1 times higher percent shrub cover. Mature forests differed from full treatments in having 25.5 times more stems 2.5–8.0 cm dbh. Understory treatments differed from full treatments in having 2.6 times lower percent shrub cover.

Table 1. Breeding bird species and nesting guild abundance per point count on mature forest (control), understory treatment, and full-treatment plots in the Arkansas Ozarks, 1993–94.

	Treatment					
	Control		Understory		Full	
Species or guild, scientific name, nesting location[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Yellow-billed cuckoo, *Coccyzus americanus*, CN	0.03	0.01	0.03	0.02	0.09	0.05
Ruby-throated hummingbird, *Archilochus colubris*, CN	0.09	0.02	0.04	0.02	0.06	0.04
Red-bellied woodpecker, *Melanerpes carolinus*, CV	0.01	0.01	0.11	0.05	0.19	0.08
Downy woodpecker, *Picoides pubescnes*, CV	0.08	0.02	0.15	0.04	0.25	0.09
Hairy woodpecker, *P. villosus*, CV	0.08	0.03	0.06	0.03	0.12	0.07
Pileated woodpecker, *Dryocopus pileatus*, CV	0.04	0.02	0.04	0.02	0.00	0.00
Eastern wood-pewee, *Contopus virens*, CN	0.32	0.04A[b]	0.70	0.08B	1.34	0.17C
Acadian flycatcher, *Empidonax virescens*, CN	0.35	0.05A	0.17	0.05B	0.03	0.03B
Blue jay, *Cyanocitta cristata*, CN	0.17	0.07	0.12	0.09	0.06	0.06
Tufted titmouse, *Baeolophus bicolor*, CV	0.17	0.04A	0.25	0.06A	0.03	0.03B
Carolina chickadee, *Poecile carolinensis*, CV	0.16	0.04	0.10	0.04	0.03	0.03
White-breasted nuthatch, *Sitta carolinensis*, CV	0.28	0.04A	0.29	0.06A	0.69	0.16B
Carolina wren, *Thryothorus ludovicianus*, CV	0.06	0.02	0.03	0.02	0.25	0.10
Blue-gray gnatcatcher, *Polioptila caerulea*, CN	0.12	0.03	0.31	0.07	0.37	0.14
Wood thrush, *Hylocichla mustelina*, UN	0.13	0.03	0.01	0.01	0.00	0.00
Red-eyed vireo, *Vireo olivaceus*, CN	2.28	0.09	2.35	0.12	1.69	0.12
Yellow-throated vireo, *V. flavifrons*, CN	0.10	0.03	0.17	0.05	0.19	0.07
Black-and-white warbler, *Mniotilta varia*, UN	0.30	0.04	0.22	0.05	0.37	0.10
Cerulean warbler, *Dendroica cerulea*, CN	0.08	0.02	0.01	0.01	0.00	0.00
Black-throated green warbler, *D. virens*, CN	0.10	0.03	0.13	0.04	0.03	0.03
Hooded warbler, *Wilsonia citrina*, UN	0.18	0.04	0.01	0.01	0.00	0.00
Worm-eating warbler, *Helmitheros vermivous*, UN	0.20	0.04A	0.04	0.02B	0.00	0.00B
Ovenbird, *Seiurus aurocapillus*, UN	0.90	0.06A	0.35	0.07B	0.09	0.05B
Indigo bunting, *Passerina cyanea*	0.10	0.03A	0.26	0.07A	0.63	0.15B
Brown-headed cowbird, *Molothrus ater*	0.03	0.02	0.11	0.05	0.06	0.04
Scarlet tanager, *Piranga olivacea*, CN	0.56	0.06	0.68	0.10	0.41	0.12
Cavity Nesters	0.87	0.08A	1.03	0.13A	1.56	0.25A
Understory Nesters	1.71	0.10A	0.64	0.11B	0.47	0.10B
Canopy Nesters—1993	4.84	0.25A	5.32	0.29A		
Canopy Nesters—1994	3.44	0.22A	3.94	0.21B	4.28	0.30B

[a] Canopy nesters = CN; cavity nesters = CV; understory nesters = UN.
[b] For statistical tests, means with same letter within rows were not different (Kruskal Wallis χ^2, $P > 0.05$). Only species and guilds showing an overall treatment effect were used in pairwise tests. Canopy nesters showed a year effect and were analyzed separately by year; df = 1 for all tests.

Canopy-, Cavity-, and Understory-Nesting Guilds

There were no between-year differences in the abundances of cavity ($\chi^2_1 = 2.7$, $P = 0.099$) or understory ($\chi^2_1 = 0.4$, $P = 0.545$) nesters on mature forest control plots. In these guilds, we found overall treatment effects for understory ($\chi^2_2 = 18.1$, $P < 0.001$) nesters, but not for cavity nesters ($\chi^2_2 = 4.75$, $P = 0.092$). Pairwise comparisons among treatments (Table 2) showed that the highest numbers of understory nesters occurred in mature forests.

Canopy nesters exhibited a between-year difference in abundance on control plots in mature forests ($\chi^2_1 = 8.9$, $P = 0.003$) and were analyzed separately by year. In 1994, more canopy nesters ($\chi^2_2 = 6.3$, $P = 0.041$) occurred on full and understory treatments than in mature forests (Table 1).

Individual Bird Species

Red-eyed vireos (*Vireo olivaceus*; $\chi^2_1 = 11.3$, $P = 0.001$) and scarlet tanagers (*Piranga olivacea*; $\chi^2_1 = 6.7$, $P = 0.010$) were the only individual species to show a significant year effect; neither species exhibited any treatment effects ($\alpha = 0.05$). Seven of 14 individual bird species analyzed showed an overall treatment effect ($\alpha = 0.05$) and were included in pairwise tests among treatments. Indigo buntings, eastern wood-pewees, and white-breasted nuthatches were most common on full-treatment plots (Table 1). In addition, eastern wood-pewees were more abundant on full treatments than on understory treatments. Conversely, ovenbirds, worm-eating warblers, and Acadian flycatchers were most common in mature forests, and tufted titmice were most abundant in mature forests and understory treatments (Table 1).

Table 2. Vegetation characteristics measured within 11.3-m-radius point counts on 3 types of plots. Control = mature forest (n = 16), understory = understory treatment only (n = 8), full = understory and overstory treatments (n = 8).

	Treatment					
	Control		Understory		Full	
Habitat characteristic	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Stems 0.01–2.5 cm dbh	182.31	12.44	152.13	12.83	270.38	32.11
Stems 2.5–8.0 cm dbh	25.50	2.85	2.37	0.77	0.00	0.00
Trees 8–23 cm dbh	61.06	4.42	38.75	4.36	47.12	8.18
Trees 23–38 cm	22.68	2.07	21.25	3.04	20.62	2.64
Trees >38 cm dbh	9.56	1.33	9.87	1.83	3.12	0.87
Canopy height	26.85	0.54	25.73	0.29	23.43	0.47
% canopy cover	82.98	0.52	82.06	0.53	79.04	1.47
% grass	2.68	0.57	2.80	1.74	3.56	1.22
% shrub	20.24	1.53	6.44	1.01	16.60	2.70
% forb	30.30	1.51	43.35	3.79	32.02	4.83
% fern	1.01	0.50	2.35	2.34	1.89	0.98
% log	2.11	0.25	3.20	0.43	5.26	0.65
% litter	43.12	2.32	42.35	3.62	41.06	5.53
Low live hits	68.31	5.97	68.13	6.73	102.88	17.90
High live hits	18.81	2.23	2.87	1.02	3.87	2.01
Low dead hits	4.37	0.57	18.00	2.92	17.87	2.55
High dead hits	0.62	0.22	1.12	0.54	1.50	0.53

DISCUSSION

Uneven-aged forest management practices used in this study significantly affected, both positively and negatively, abundances of several breeding bird species and nesting guilds in the Arkansas Ozarks. Acadian flycatchers, ovenbirds, worm-eating warblers, and understory nesters were all more abundant in mature forests than on both full treatments and understory treatments from which understory trees and shrubs were heavily cut. In addition, the lower percent canopy cover on full-treatment plots may be avoided by these forest understory species. High percent canopy cover was important for breeding Acadian flycatchers, ovenbirds, and worm-eating warblers in northwest Arkansas (Shugart and James 1973, Smith 1977).

The effects of understory removal on breeding birds are essentially unknown. Droege (1985) reported no change in bird species diversity, richness, or composition 1 year after an understory herbicide treatment that resulted in a 67% decrease in understory foliage density. However, strong avian site fidelity or population saturation in adjacent forest areas may have caused the lack of a treatment effect (Droege 1985). Rodewald (1995) documented heavy use of forest understory structure and tree species by foraging worm-eating, black-and-white (*Mniotilta varia*), and hooded (*Wilsonia citrina*) warblers in northwest Arkansas. In addition, McShea and Rappole (1992) demonstrated a positive correlation between understory vegetation density and species diversity of understory-nesting birds. The duration of the effects of understory removal on forest understory birds is unknown but may last only a few years for some species. However, species that forage extensively in larger understory trees (i.e., worm-eating warbler; Rodewald 1995) may be affected for a longer period of time.

Tufted titmice were most abundant in mature forests and understory treatments, suggesting an association with closed canopy forest; this result was also reported by Conner et al. (1983). Also, although not statistically tested, due to small sample sizes, there did seem to be a strong pattern of absence for wood thrushes (*Hylocichla mustelina*) and hooded and cerulean warblers (*Dendroica cerulea*) on both types of managed plots. Two of these species, cerulean warbler and wood thrush, warrant future attention because they are species of high management concern in Midwestern forests (Thompson et al. 1993), and they have experienced significant rangewide population declines (Peterjohn and Sauer 1993).

Other birds seemed to favor the open habitat created by forest management activities. For example, in 1994, the canopy-nesting guild was more numerous on full and understory treatments than in mature forests. This result may have been due, in part, to higher abundances of eastern wood-pewees on managed plots. Pewees may experience increased aerial foraging efficiency in more open habitats. The higher abundances of pewees on managed plots is noteworthy because populations of this species are believed to be declining (Peterjohn and Sauer 1993). The indigo bunting, an early successional or forest edge species, was most abundant on full-treatment plots, suggesting selection for the most open forest habitat. We are uncertain as to why white-breasted nuthatches were most common on full-treatment plots.

Although we documented patterns of avian abundance among the forest treatments, abundance may be a misleading indicator of nesting success (Van Horne 1983). In our study, no direct assessment of nesting success was made, but field observations in the first year following treatment suggested understory birds rarely nested on managed plots. Indeed, nesting habitat for some understory species was nearly entirely removed during management. An assessment of nesting success is needed in future studies of this forest management practice.

Our findings are important because few data exist on the effects of uneven-aged forest management practices on birds in eastern deciduous forests. Our results are fairly consistent with those of Annand and Thompson (1997) who studied effects of several different forest management practices, including single-tree selection and group-selection cutting, on breeding birds in Missouri Ozark forests. They reported that ovenbirds and wood thrushes were most abundant in mature forests, while Acadian flycatchers and red-eyed vireos were most common in group-selection cuts and mature forests.

MANAGEMENT IMPLICATIONS

Timber management activities in the Ozark-St. Francis National Forest are concerned primarily with the production of oak and hickory. The practice of understory removal is attractive to forest managers because it should enhance oak and hickory regeneration. However, because treated plots had, at least temporarily, significantly lower abundances of forest understory birds, managers using such practices should consider reducing the amount of understory vegetation removed. Future experiments could examine effects of removing varying amounts of understory vegetation on both bird populations and forest regeneration. Acceptable regeneration might be obtained by cutting lower amounts of understory tree and shrub species important for forest birds. In addition, such a practice may reduce the period of time needed for adequate understory habitat to regenerate.

Our research provides managers with insight concerning the practice of understory removal in particular, and its effect on forest bird abundance. However, the generation of specific management guidelines from this research would be premature, especially given that avian reproductive success was not examined. Forest management practices used in this study show promise in the development of methods that consider both the goals of forest managers and the requirements of forest birds. Additional research is needed to assess the long-term effects of this and other uneven-aged forest management practices on the abundance and nesting success of bird populations.

ACKNOWLEDGMENTS

Financial support was provided by the Southern Research Station of the U.S. Forest Service. We thank Forest Service personnel J. B. Andre, D. L. Graney, P. A. Murphy, J. S. Osborne, and J. S. Self for their assistance in this project. M. C. Brittingham, D. A. James, A. D. Rodewald , G. L. Wheeler, and anonymous reviewers commented on the manuscript. Statistical advice was generously provided by J. A. Baker, R. W. McNew, D. G. Catanzaro, and J. E. Dunn. We thank J. Bider, R. King, K. M. Lohraff, and L. Pomara for field assistance, data entry assistance, or both.

LITERATURE CITED

ANNAND, E. M., AND F. R. THOMPSON, III. 1997. Forest bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management 61:159–171.

ASKINS, R. A., J. F. LYNCH, AND R. GREENBERG. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7: 1–57.

CHADWICK, N. L., D. R. PROGULSKE, AND J. T. FINN. 1986. Effects of fuelwood cutting on birds in southern New England. Journal of Wildlife Management 50:398–405.

CONNER, R. N., AND C. S. ADKISSON. 1975. Effects of clearcutting on the diversity of breeding birds. Journal of Forestry 73:781–785.

———, J. G. DICKSON, B. A. LOCKE, AND C. A. SEGELQUIST. 1983. Vegetation characteristics important to common songbirds in East Texas. Wilson Bulletin 95:349–361.

———, J. W. VIA, AND I. D. PRATHER. 1979. Effects of pine–oak clearcutting on winter and breeding birds in southwestern Virginia. Wilson Bulletin 91:301–316.

DROEGE, S. 1985. The response of an Adirondack mountain bird community to understory defoliation. Thesis, State University of New York, College of Environmental Science and Forestry, Syracuse, New York, USA.

FINCH, D. M., AND P. W. STANGEL, editors. 1993. Status and management of Neotropical migratory birds. U.S. Forest Service General Technical Report RM-229.

FRANZREB, K. E., AND R. D. OHMART. 1978. The effects of timber harvesting on breeding birds in a mixed-coniferous forest. Condor 80:431–441.

HAGAN, J. M., III, AND D. W. JOHNSTON, editors. 1992. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, D.C., USA.

HUTTO, R. L., S. M. PLETSCHET, AND P. HENDRICKS. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593–602.

JAMES, F. C., AND H. H. SHUGART, JR. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727–736.

MANNAN, R. W., AND E. C. MESLOW. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. Journal of Wildlife Management 48:1219–1238.

MARTIN, T. M., AND D. M. FINCH, editors. 1995. Ecology and management of Neotropical migratory birds. Oxford University Press, Oxford, United Kingdom.

MCSHEA, W. J., AND J. H. RAPPOLE. 1992. White-tailed deer as a keystone species within forest habitats of Virginia. Virginia Journal of Science 43:177–186.

MEDIN, D. E. 1985. Breeding bird responses to diameter-cut logging in west-central Idaho. U.S. Forest Service Research Paper INT-335.

MORRISON, M. L. 1992. Bird abundance in forests managed for timber and wildlife resources. Biological Conservation 60:127–134.

PETERJOHN, B. G., AND J. R. SAUER. 1993. North American Breeding Bird Survey annual summary 1990–1991. Bird Populations 1:1–15.

ROBBINS, C. S., J. R. SAUER, R. S. GREENBERG, AND S. DROEGE. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences of the United States of America 86:7658–7662.

ROBINSON, S. K. 1997. The case of the missing songbirds. Consequences 3:3–15.

RODEWALD, P. G. 1995. Effects of uneven-aged forest management on migrant and resident birds in oak–hickory forests of the Arkansas Ozarks. Thesis, University of Arkansas, Fayetteville, Arkansas, USA.

RUDNICKY, T. C., AND M. L. HUNTER. 1993. Reversing the fragmentation perspective: effects of clearcut size on bird species richness in Maine. Ecological Applications 3:357–366.

SAS INSTITUTE. 1989. SAS/STAT user's guide. Version 6. Fourth edition. SAS Institute, Cary, North Carolina, USA.

SHUGART, H. H., JR., AND D. JAMES. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62–77.

SMITH, D. M. 1986. The practice of silviculture. Eighth edition. John Wiley & Sons, New York, New York, USA.

SMITH, K. G. 1977. Distribution of summer birds along a forest moisture gradient in an Ozark watershed. Ecology 58:810–819.

SOKAL, R. R., AND F. J. ROHLF. 1995. Biometry. Third edition. W. H. Freeman, New York, New York, USA.

STRELKE, W. K., AND J. G. DICKSON. 1980. Effect of forest clear-cut edge on breeding birds in East Texas. Journal of Wildlife Management 44:559–567.

SZARO, R. C., AND R. P. BALDA. 1979. Bird community dynamics in a ponderosa pine forest. Studies in Avian Biology 3:1–66.

THOMPSON, F. R., W. D. DIJAK, T. G. KULOWIEC, AND D. A. HAMILTON. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management 56:23–30.

———, S. J. LEWIS, J. GREEN, AND D. EWERT. 1993. Status of Neotropical migrant landbirds in the Midwest: identifying species of management concern. Pages 145–158 *in* D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. U.S. Forest Service General Technical Report RM-229.

VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901.

WEBB, W. L., D. F. BEHREND, AND B. SAISORN. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildlife Monographs 55.

YAHNER, R. H. 1987. Use of even-aged stands by winter and spring bird communities. Wilson Bulletin 99:218–232.

Received 15 June 1997.
Accepted 31 March 1998.
Associate Editor: Lutz.